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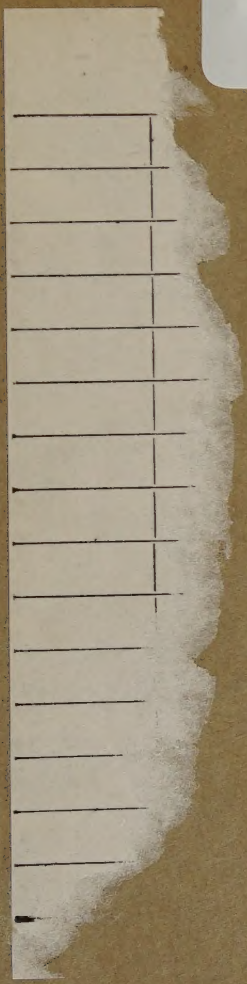

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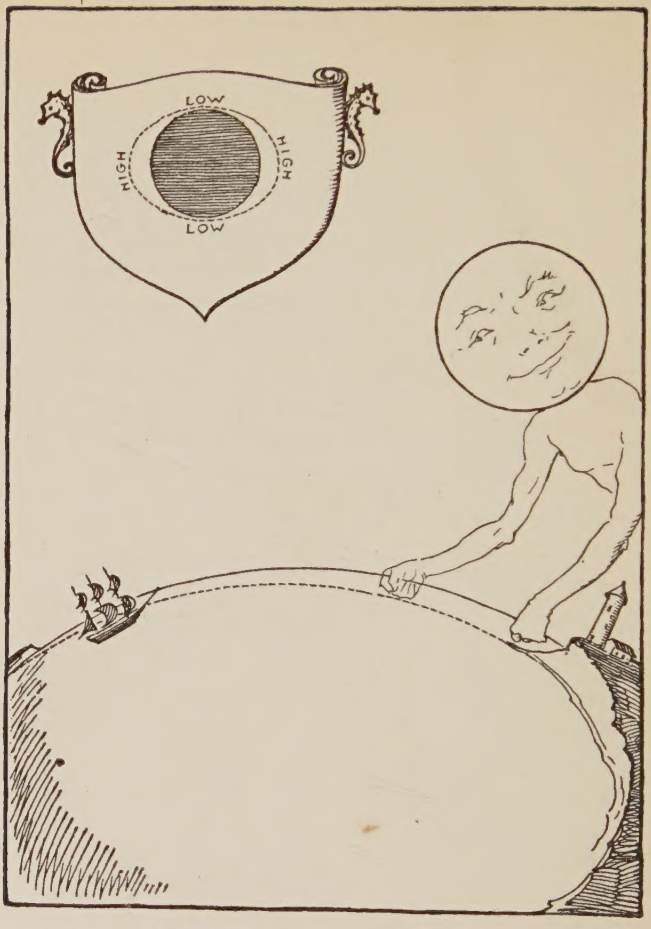
Publishers' Note

This book presents in popular form the present state of science. It has been reviewed by a specialist in this field of knowledge. An excerpt from his review follows:

> *"I am glad to see this successful effort to popularize Physics and bring some of its simpler laws within the grasp of younger minds."*

Signed ALBERT A. MICHELSON
Professor Emeritus of Physics
The University of Chicago



The gravity of the moon attracts the water in the ocean which tries to follow the moon

THIS PHYSICAL WORLD

By

JANET POLLAK

Drawings by

LENARD HOLMES

THOMAS S. ROCKWELL COMPANY
CHICAGO
1930

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CONTENTS

I GRAVITY 11

Why do things fall down? What makes tides? Why is the earth round? Why can we drink through a straw? How does ink get into a fountain pen? Why can we not feel air pressing against us? Why do we say water seeks its own level? Why is it easier to swim in salty water? What keeps balloons up in the air? Why is it hard to balance on one foot? How does a submarine stay under water?

II PUSH AND PULL 34

Why can we not put Humpty Dumpty together again? Why do our clothes get wet when it rains? Why is it harder to erase ink marks than pencil marks? Why do we slip when we walk on ice? Why do we slip in the bathtub? Why do we get fire by rubbing two sticks together? Why do automobile tires wear out? Why do we oil machinery?

III WHAT HEAT CAN DO 48

Why does water sometimes turn to ice? What makes water boil? Why do doors stick in the summer time? Why do floors sometimes make a crackling sound? Why can cement roads not be made in one piece?

IV THINGS IN MOTION 57

Why does a ball bounce? How can a top stand on its point when spinning? What keeps the earth in its orbit? Why does a bicycle keep moving after we stop pedaling

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it? Why is it hard to stop roller skates quickly? Why does swimming make us travel in water?

V WHY WE SEE 67

Why is the night dark? Why can we see through a window pane? What is a mirror? Why can we see ourselves in a window at night? Why do the stars twinkle? What is color? What are dyes? What makes a rainbow? What is iridescent glass? What makes the sky blue? Why are we cooler in white clothes in the summer time? How does a thermos bottle work? How is the earth warmed? How does a fire warm us?

VI WHAT WE HEAR 88

What is sound? What makes a room sound proof? What makes an echo? Why do we see lightning before we hear thunder? Why does a doctor use a stethoscope? What makes the music in a phonograph?

VII ELECTRICITY 99

Why does a compass point north? How is a compass needle magnetized? Why do we get a shock if we touch someone after walking on a carpet? What is an electric current? What is a conductor of electricity? What is insulation? Why can birds sit on electric wires without being hurt? What happens when a fuse blows out? What causes the light in an incandescent lamp? How do we get heat by electricity?

LIST OF ILLUSTRATIONS

THE MOON ATTRACTS THE WATER	*frontispiece*
THE SODA WATER RUSHES UP THE STRAW	17
WATER WILL SEEK ITS LEVEL	21
WHEN IRON WILL FLOAT	25
THE LEANING TOWER OF PISA	31
WE SLIDE ON THE WATER	41
ICE NEEDS MORE ROOM AS IT FREEZES	51
THE MOLECULES NEAR THE TOP JUMP AWAY	53
WHY THE BALL BOUNCES	58
ALL THE MOLECULES ARE MOVING AROUND	61
LIGHT RAYS TRAVELING TO THE MIRROR	72
A PRISM WILL BEND A RAY OF SUNLIGHT	77
THE RAINBOW IS DIVIDED SUNLIGHT	79
THE THERMOS BOTTLE HAS A DOUBLE WALL	83
LIGHT TRAVELS MUCH FASTER THAN SOUND	95
THE AIR CARRIES THE SOUND	96
BIRDS CAN SIT ON ELECTRIC WIRES	107

Chapter I

GRAVITY

ALL around us every day things happen so naturally that we never stop to think about them and wonder why they always happen just that way. But once in a while we do stop in our work or play and try to figure them out.

Why do things fall down?

There is one fact that affects everything we do and see. That is the fact that things always fall *down*. If a ball is thrown up in the air, it never stays there; it comes right down again. When the stem of a leaf is loose from the branch, it never floats way up into space and stays there; the leaf flutters down to the ground. It is convenient for us that this is so and we feel it is right that the world should be this way. But when we stop to think, we sometimes wonder how it happens that things always fall down and never up.

If we ask someone about it, we are told that gravity makes things fall down. Then we want to know what gravity is. Gravity is a force which attracts one thing to another. This force called gravity works something like a magnet. Any two things in the universe try to draw close to each other. The bigger a thing is, the more power it has to pull other things toward it. The earth is so huge—so much larger than anything upon it—that it has more of this power than anything on the earth. That is why it can pull everything down to it.

When someone throws a ball up in the air, this great force in the earth will pull the ball down again. The earth is really moving up towards the ball, too. But the earth is so very big that it moves up only the tiniest bit. It moves so very little that we cannot notice it move at all. All we really can see is that the ball moves down to the earth. A leaf falls down because the earth is always pulling on it, and when the stem gets weak enough it breaks off, and the leaf is pulled down to the ground.

If we throw a stone out of the window it falls because the earth is pulling it. The longer the pull lasts the faster the stone will fall, although the earth's pull (the *weight* of the body) does not change.

The stone will gain more speed when dropped from the top of a high building than when dropped from a first story window, because the pull of gravity has had a longer time in which to increase its speed.

A body moving at a given speed is said to have a certain amount of momentum, and any force, a push or a pull, must act for a certain length of time to generate a given amount of momentum. The greater the force, and the longer the time, the more the momentum will be.

An automobile or a railroad train always starts slowly and gains speed steadily as the engine pulls.

What makes tides and waves in the ocean?

The moon is much nearer the earth than any of the stars, and it has this same power of gravity that the earth has. Because it is quite

near the earth, the moon attracts the water in the ocean. The moon is not close enough to make the water rise up toward it very high, but it does draw the water up a little. On the side of the earth nearest the moon the water of the ocean is pulled by the force of gravity more, and on the side away from the moon the water is pulled less, than the solid earth between. The change in the water level is not much but it is enought to cause high tides on the sides of the earth nearest to and farthest from the moon. Low tides occur at the points midway between the high tides. As the moon moves around the earth the tides follow it. At any place there are two high and two low tides each day.

All other bodies of water, such as lakes and seas, have tides, too. But they are so much smaller than oceans, that they are not pulled very much by the moon, and we do not notice that the water shifts from one side to the other.

Why is the earth round?

Before we can understand why the earth is in the shape of a ball, or sphere, we have to know

something about what it is made of. Everything in the whole universe is made up of tiny particles called molecules. The earth, the stars, the air, and everything we know about is made up of millions and millions of molecules. They are so small that it is impossible to see one even under a powerful microscope.

They are so small that it would be impossible to count the number of molecules there are in the piece of metal that is used for the head of a pin. The reason there are different kinds of substances in the world is that there are different kinds of molecules. Some of them go together to make wood, some make iron, some make water, some make air, and so on. Molecules always try to get as close together as possible, although they are always moving about.

The earth was made from a part of the sun which flew away from the sun into space. When that happened, the part of the sun that was to be the earth was nothing but a mass of burning liquid and gas. Gradually it cooled off and changed to what we know as the earth

today. But while it was still hot, the molecules were spinning and jumping around very fast, and trying to crowd just as close together as they could. And as they crowded together and tried to fit into as small a space as possible, they formed into a great ball. They took that shape, because a sphere takes up less room for the same amount of matter than any other shape does.

Why can we drink soda through a straw?

If we put one end of a straw into a glass of soda water, and the other end into our mouth, we can draw the soda up through the straw very easily. Usually we do this without having to think about what we are doing. But if we know that gravity pulls everything down, we wonder how it happens that the soda water can rise up in the straw. If we stop to think about what we are doing, we notice that we draw in our lips as if we were sucking up air from the straw. That is exactly what happens. As we suck in the air, the soda water rushes up into the straw to take the place of the air.

As soon as we take the end of the straw out of our mouth, the air around it will push its

The soda water rushes up the straw to take the place of the air that was sucked out

way back into the straw, and force the soda water out of the straw and into the glass again. This happens because air has pressure. Although we cannot see it, air is always pressing against everything. We cannot feel it pressing against ourselves because it is pushing as much from one side as from the other. There is never a space in the world that is really empty. If nothing else is there, it is filled with air. When we first put the straw in our mouth it is filled with air which keeps out the soda water. But as soon as we draw in the air, something else must take its place, because the air over the soda water is pressing down on it. There is no air left in the straw to press back. So the soda water is pushed up into the straw.

If we take the straw out of the glass, and close one end of it, and then draw in the air from the other end, the straw will flatten out. We can then see that air has pressure. When there is air inside the straw it pushes just as hard as the air is pushing outside the straw. But if we take away the air inside, the pressure of the air out-

side the straw will push the sides of the straw together. Instead of being round and hollow like a tube, the straw will look like a flat strip.

How does the ink get into a fountain pen?

Before we put ink into a new fountain pen, the tube inside the pen is filled with air. If we set the pen in a bottle of ink, nothing happens, because this air presses on the ink and keeps it from rising up in the pen. But when we push the button at the top of the pen, we force the air out of the rubber tube and out of the pen. When we release the button there is a vacuum in the rubber tube and the ink rushes up to take the place of the air. This happens because the air around the ink presses down on it and pushes it into the empty tube. As long as there is air in the tube, it pushes just as hard on the ink as the air around the ink does, and the ink will stay in the bottle.

Why do we make two holes in a can to get a liquid out?

To open a new can of evaporated milk, we punch two holes in the top of the can. We do this because if we punch only one hole in it, the milk does not come out easily. A little milk will drip out that way, but it takes a long time

to get enough to use. The reason the milk doesn't pour out of a single hole is that the air outside is pressing on the milk, trying to force it back into the can. But as soon as we make another hole, the milk will run out freely. It can do this because the air pushes against the milk at one of the holes, and as it forces its way into the can, it drives the milk out of the other hole in the can.

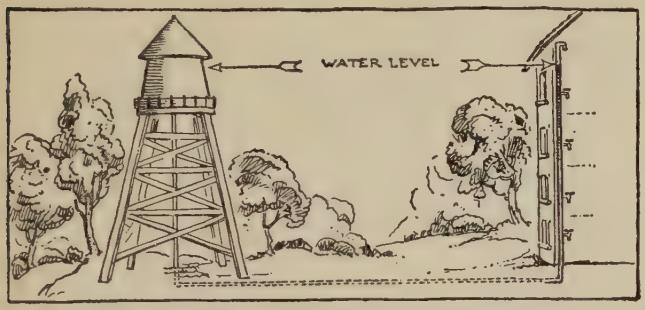
Why can we not feel air pressing against us?

Although we cannot see air, it has a great deal of pressure. It is pushing against us all the time. And if we didn't have something inside us to press just as hard as the air presses from outside, we would be crushed by this outside pressure. But the air inside our bodies, and the blood press just as much as the outside air does, so that we do not notice the force of the air against our bodies.

Why do we say water seeks its own level?

When we turn on a faucet, and water runs out, it does this because gravity pulls the water down. But if gravity pulls everything downward, how does water rise in pipes to all the different stories of a house, no matter how high

the building is? We are told this happens because water seeks its own level. That means that water will always flatten out on its surface. If we scoop up a bucketful of water from a well,



The water will run in the pipes of the building just as high as it stands in the tower

it doesn't leave a hole in the water. The water will immediately flatten out and fill up the space. To do that, the water pushes down.

It is easy to see how water seeks its own level, if we trace it back from the faucet to the place where the water supply is kept. On some city houses, we see great tanks full of water on the roofs. Sometimes all the water for a city is kept in a big reservoir which is built in a place

that is just as high as the highest building. The water is kept there because water will always rise up in the pipes to the same level as the water in the reservoir. Whenever any water is used, the water that is left in the reservoir will flatten out and this pushes the water in the pipes until it is just as high as the water in the reservoir. As long as the water supply is kept just as high as the tallest building, the water will run up through the pipes to the top floors of the buildings. Then if we turn on the tap, the water will rush out and gravity will make it flow downward, into the drain.

The water that spurts up in a fountain will rise almost as high as the water in the reservoir it comes from. In the country, water usually comes through pipes from a well near the house. If the well is on a hill so that it is just as high as the top of the house, the water will rise in the pipes to all the floors of the building. But if the top of the house is higher than the well, the water will not rise up all the way. That is why in some farmhouses we can have running water

only in the kitchen and do not have any lavatories upstairs where the bedrooms are.

Why does cream always rise to the top of the bottle?

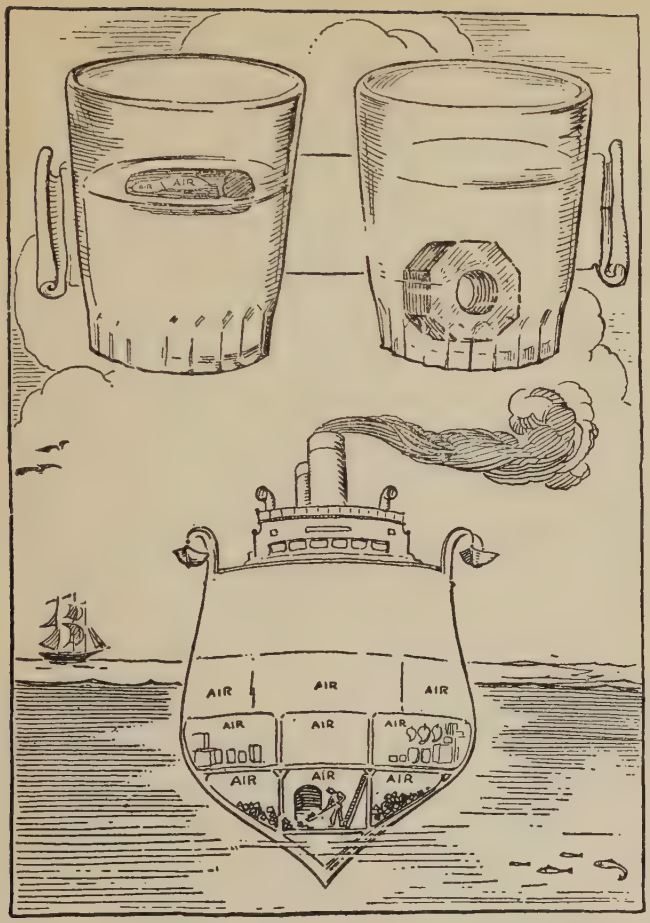
If we shake up a bottle of milk, the cream mixes with the plain milk. But if we let it stand quietly for a while, all the cream will rise up to the top of the bottle again. What is really happening is that the plain milk is sinking to the bottom of the bottle because it is heavier than cream. Liquids that are heavy will always sink and force lighter substances toward the top.

Why do iron ships float?

We know that iron is heavier than water, because if we drop a piece of iron in water, it sinks to the bottom right away. Wood is lighter than water, and we often see pieces of wood floating in the ocean. So for hundreds of years men made all their ships of wood because they knew it would float. They were afraid to build iron ships, even though iron is stronger and would last longer. They knew that iron sinks and did not know how to build a ship of iron so that it could float. But at last someone found a way to build a ship of iron or

steel that would float. To understand how this was done, we have to know why some things float and others do not. We say a thing can float in water because it is lighter than the water. What we mean is that the thing is lighter than the water that it displaces. When we drop a piece of wood into the ocean, the wood pushes enough water away to make room for itself. The wood is equal in weight to the amount of water it pushes away, so it floats. But when a piece of iron pushes enough water away to make room for itself, it weighs *more* than that amount of water, so it sinks. So if a boat were made of solid iron, it would weigh more than the water it would push away, and the ship would sink. But iron or steel ships are made with great empty spaces which are filled with air. Air is much lighter than water. So the iron ship, with all the air that is in it, does not weigh as much as the water that it pushes away when it slides into the ocean. That is why it is able to float.

Anyone who has tried swimming in the



When the iron pushes away a greater weight of water than the weight of the iron, it will float

Why is it easier to swim in salty water?

ocean, and in a lake or brook, knows that it is easier to keep afloat in the salty water of the ocean than in the fresh water of a lake or brook.

We weigh the same amount in either kind of water. We also do the same things to keep ourselves on top of the water, but we don't have to work as hard to stay there in the ocean. The reason is that when we push away a certain amount of ocean water to make room for ourselves, we are really pushing away water *and salt.* This water and salt together weigh more than pure water does in the lake. So we say that salt water weighs more than fresh water. Because it weighs more, it is easier for us to stay afloat in salty water than in fresh water.

But our bodies are heavier than any kind of water, and if we did not breathe while swimming we would sink. Every time we take a breath of air into the lungs, they expand to make room for the new air. As the lungs spread out, they make us a little bit bigger. Then we take up more space in the water, and have to push more water out of the way. But because the air

that fills the lungs is much lighter than the water it keeps us floating, just as iron ships float because their extra spaces are filled with air.

Why do icebergs float?

We know that icebergs are nothing but water which has frozen. Now because the surface of the ocean is flat, except for the waves, we would expect frozen water to have the same weight as when it is not frozen, and to fit into the same space. If that were true, icebergs would not stick up out of the water. But water has a strange habit. Instead of becoming larger or expanding when it is warm, and shrinking or contracting when it freezes, it gets bigger when it turns to ice. So the iceberg has to push some more water out of the way in order to have enough room for itself. The iceberg weighs exactly as much as all the water that is pushed aside, and so it floats on top of the water. It is fortunate that this happens. For if icebergs did not float, we could never see them, and ships would not be able to steer out of their way.

The Graf Zeppelin traveled all around the

world in the air. It carried many passengers, and food and places to sleep. It has machinery, which is very heavy. The big silk balloon part is covered with a metal called aluminum. Every one of these things is heavier than the air. If a man had stepped out of the airship, he would have fallen right down to earth. The machinery would not stay up by itself. Yet the Zeppelin with all these things aboard it could float high up over the earth. This was made possible, because the silk balloon inside the aluminum was filled with hydrogen. Hydrogen is a gas which is much lighter than air. Things float in air, the same way they do in water. There was so much hydrogen in the airship that even with all the other things in it, the Zeppelin did not weigh any more than the air it pushed away to make room for itself. That is why it could float up in the air.

What keeps balloons up in the air?

Why is it hard to balance on one foot?

Whenever we stand on one foot, we find it difficult to keep our balance. We sway back and forth, in trying not to fall. And when we see that we are about to fall, we can save our-

selves by quickly putting down the other foot. As soon as both feet are on the ground again, it is easy to keep our balance.

Our two feet are the base on which our body is built, just as the foundation of a house is the base on which it is built. When we stand on both feet, the center of our weight is directly over them. Nothing can stand erect unless the center of its weight is directly over its base. When we stand on only one foot, that makes the base very much smaller. Then the center of weight in our body is not directly over the foot. And when the center of weight of anything is not directly over the base, it cannot stand upright but will always fall.

A building can stand, no matter how many stories high it is, if the center of its weight is over the base of the building. But if a straight line drawn from the center of weight in the building, down to the ground, touches the ground *outside* the base of the building, the building will fall.

Many hundreds of years ago, in a town in

Why does the Leaning Tower of Pisa not topple over?

Italy, called Pisa, a beautiful tower was started. When the tower was about thirty-five feet high, the builders found that it had begun to sink into the earth on one side. In those days it took a great deal of time to build, and so the men who were erecting the tower did not want to undo their work and begin all over again to make the tower straight. They continued to build slowly on the slanting foundation, because they knew that if the center of weight of the whole tower was above the base, the tower would stand. They finished the tower in a slanting position, and it has remained that way for 800 years.

How does a submarine stay under water?

If submarines were built to travel below the surface of the ocean without ever traveling on the water as other boats do, it would be easy to understand how they were made. In that case it would be necessary only to make them heavier than the amount of water they are to replace. But the truth cannot be as simple as that, because if they were built in that way, they would immediately sink to the bottom of the ocean.

As long as the center of weight of the tower is over the base the tower will stand

Submarines are made so that they can travel on the surface as other ships do. They are also able to regulate the depth under the surface to which they go. They are built light enough to float on the water. But they have in them empty chambers filled with air. When they wish to dive below the surface, these chambers are opened to let in water. This water gives the ship added weight, which makes the submarine heavy enough to sink. The more water is let into these chambers, the farther down the boat will sink.

Submarines also have diving rudders, or hydroplanes as they are sometimes called. There are two sets of these hydroplanes, a pair placed fore and a pair placed aft on the ship. Those which are aft, or at the stern of the submarine, are like fins on a fish. They help stabilize the ship and keep it in a steady, horizontal position in the water when the submarine is traveling below the surface of the ocean. The hydroplanes placed forward, or near the bow of the submarine, are movable.

They can be tilted at varying degrees to aid the ship in diving to a lower depth in the water or rising nearer the surface. Just as the wings of an airplane are tilted at different slants so the airplane can rise higher or descend to a lower level in the air, these diving rudders at the fore of the submarine make it easier for the ship to move up or down in the water.

There are also in the submarine tanks of compressed air. This compressed air has more pressure than ordinary air. When the ship wants to rise to the surface, this compressed air is pumped into the chambers, and it forces the water out again.

The farther down into the ocean we go, the more pressure there is in the water. So submarines cannot sink very far or they would be crushed by the pressure of the water. At a distance from shore, the ocean is many miles deep, but a submarine does not go down much below the surface.

Chapter II

PUSH AND PULL

Why can we not put Humpty Dumpty together again?

HUMPTY DUMPTY was really made of an egg, and if we drop an egg on the floor, we know that we can never put all the pieces together and make it whole again. Why? Just as every other kind of matter is, the eggshell is made up of millions of tiny particles which are called molecules.

All molecules in an eggshell are of the same kind, and they stick together to make the eggshell one smooth piece. When molecules do this, we say they cohere or have cohesion. Without this cohesion nothing in this world would be solid. Everything would be a gas like the air, because molecules in the air do not stick together. The closer they stick together, the harder or tougher a thing is. The molecules in the eggshell stick quite close together

and make the shell hard, but it is thin and not very tough.

Because it is thin, it breaks into many pieces when we drop it. This happens because it hits the floor with a great deal of force and this makes the molecules separate in some places so that we have a lot of little pieces instead of one whole eggshell. Once it has broken, it cannot be put together again, because we can't get the molecules near enough each other to make them stick. If the pieces are not too small, we might make them stay together with glue. We could do this because glue is sticky, which means it has a great deal of adhesion and can make two parts stick together. Part of the glue touches one piece and part touches another piece. All the particles in the glue will stick together and thus hold the broken pieces together.

There are many things that have great cohesion. We can pull and pull on a piece of iron and not separate one part from another. Only when we hit it very hard with something strong will it break. And after it is broken, it cannot

be put together again unless it is heated. When iron is made very hot, it becomes soft. If the two pieces are hammered together while they are soft, the iron will form one single piece again when it gets cool and hard. This is what is called welding.

Why do our clothes get wet when it rains?

If the gravity of the earth makes raindrops fall to the ground from the clouds, then all the drops that touch us as they fall should roll right off again. And if gravity pulled all the raindrops off our clothes, we should be perfectly dry even if we had no umbrella. But there is a power in the water which makes some of it stick to our clothes, instead of falling right down to earth. The molecules in the water will try to stick to the things they touch, in the same way they try to stick together. The gravity in the earth is so strong that it will pull most of the rain down to the ground. But the raindrops that touch our clothes will stay there. This is because the power to stick is stronger, when things are close together, than the gravity of the earth.

If we put our hands in a basin of water, some of the water will stick to our hands when we take them out. Gravity will pull on most of the water and keep it down in the basin. But the water that is very close to our hands will have enough power to stick to the skin, in spite of the force of gravity which is trying to pull it off. This power which molecules have to stick to things is called adhesion.

If we touch a pool of water and then raise a finger a little bit, the water will cling to the finger. That is because the water that is close to the finger is trying to stick to it. But gravity is so strong that most of the water will stay down. Only a little of the water that really touches the finger will stay on it when we lift the finger up higher.

When we are turning the pages of a book, sometimes we wet our fingers and that makes our task easier. This is because the water on the fingers tries to stick to the page and to the fingers at the same time. When we move the fingers, the page moves with them.

Why is it harder to erase ink marks than pencil marks?

When we use an eraser to rub out what we have written on a piece of paper with a pencil, it is usually easy to get the page quite clean again. None of the marks left by the pencil are left, and we can write in the same space again. But when we have written something in ink, we cannot rub out every bit of it. Some of the ink-marks remain on the paper, no matter how hard we rub. The reason for this is that when we make marks with a pencil one thing happens to the paper, and when we make marks with ink a different thing happens.

As we move a pencil across a page, tiny particles of the lead are left wherever the point touches the paper. The particles stick to the paper because of adhesion. Wherever the point touches the paper, the molecules in the lead pull off from the whole piece of lead and stay on the paper. But these particles stay on the surface of the paper. They do not sink into it, or become part of the paper. We notice this if we brush our hand across the page. The writing will get smudged. So when we rub the page

with an eraser, little particles of lead come off the paper and stick to the eraser, or get mixed with the tiny pieces of rubber that remain like crumbs on a page when we have finished rubbing with the eraser.

But when we write in ink, part of the ink soaks into the paper, and the part which stays wet on top evaporates. When we try to erase these marks after they are dry, we cannot get them all out without rubbing a hole in the page. The ink has gone right into the paper and become part of it. The power which the paper has to draw ink into it is called capillary attraction. If we could write with ink on a piece of glass, it would be quite easy to rub it all out again when it was dry. This is because glass does not have the power to absorb a liquid. Things that can absorb a liquid have tiny empty spaces in them between the particles of which they are made. Usually these spaces are so small that we cannot see them. But they are like very small tubes, and the liquid will run up into these tubes. We cannot see the spaces

in a piece of paper, but they are there, and the ink runs into these tube-like places. The kind of paper that blotters are made of has even more spaces in it than ordinary writing paper. That is why we can use it to absorb large blots of ink or paint or water. In glass there are no such spaces between the particles. So the ink stays on the surface of the glass and can be very easily erased.

If we take two lumps of loaf sugar, and set them in a saucer one on top of the other, and put just a few drops of coffee in the bottom of the saucer we can see easily how capillary attraction works. If we watch for a few seconds, we will see first the lower lump of sugar become brown in color as the coffee rises up into the tube-like places in the sugar. And if we watch for a little longer, the coffee will also rise up into the second lump of sugar.

Why do we slip when we walk on ice?

When there is ice on the street, it is much harder to walk without slipping and falling than when the streets are dry. And it is also harder to walk on a bare floor that has been

The rubbing of the shoe makes a little of the ice melt and we slide on this water

polished than on a rug or carpet. To understand why this happens, we have to learn why we do not slip on a clean street or on a carpet.

Each time we put a foot down, the sole of our shoe rubs against the asphalt or cement of the sidewalk. This rubbing holds the foot down until we put the other foot forward, and lift up the first foot. The same thing happens when we walk on a carpet or rug. When two things rub against each other this way, we say they cause friction. If we could look at a piece of the street under a microscope, we could see that it really is not very smooth or even. We could see that there are tiny bumps and ridges in it. When things are not very smooth they have friction.

Now things that are smooth have almost no friction. Ice is fairly smooth but it has some friction. Now when our foot comes down on the ice, the rubbing of the shoe on the ice makes a tiny bit of the surface melt and form drops of water, which has practically no friction. Our shoes slide on this film of water. So if we are

not careful as we walk on the ice our feet keep slipping and we are likely to lose our balance.

A floor that is waxed becomes very smooth and has almost no friction. But a carpet is thick and soft, and so it is easy to walk on a carpet without slipping. People wax floors when they want to dance, because in dancing they want their feet to slide along the floor. It is difficult to dance on carpet, because the friction makes our shoes stick when we try to slide. People often sprinkle sawdust or ashes on ice. This makes the surface uneven, instead of smooth, and then we can walk on it without slipping. When our shoes are new, the soles are quite smooth. That is why we sometimes slip on a clean pavement before the soles of our shoes become rough and uneven from wear.

Why do we slip in the bathtub?

Most bathtubs are made of porcelain which is fairly smooth. But porcelain has enough friction so that when we stand in a dry tub, we are safe and not likely to slip and fall. But if the bottom of the tub is wet, there is a film of water between the tub and our feet. And as water has

almost no friction, it is difficult to stand in the wet tub without slipping.

Friction is very important. It gives forth heat besides preventing things from slipping. We rub our hands together when they are cold, because that warms them. It is friction which causes that warmth.

Why do we get fire by rubbing two sticks together?

When two hard substances are rubbed together for a long time they get very hot. If we continue to rub, they finally grow so hot that sparks fly out. Men first kindled fires by rubbing two pieces of wood together until they became hot enough to give off sparks. They would hold the two pieces over a bunch of twigs and leaves, and the sparks would fly into this heap. So a fire would be started.

What happens when a match is struck?

In a simple way, a match is lighted in much the same manner that fires were first built. Men struck two stones together because they could get a spark more quickly than by rubbing two pieces of wood together. They would let the spark from the stones set fire to the kindling.

In the old matches, it was not the wood that

first began to burn. Phosphorus bursts into flame at a much lower temperature than wood. So the top of the match was made of phosphorus. When this was rubbed on a rough surface, it ignited without becoming very hot. Under the phosphorus head of the match was a little sulphur. Sulphur needs a little more heat to burst into flame. But the flame of the phosphorus was enough to make the sulphur catch fire. And when the sulphur began to flame it gave off enough heat to make the wood of the match begin to burn, too. If the whole match were made of wood, no matter how long a time we rubbed it on sandpaper, we probably could not get it hot enough to flame up.

Why do automobile tires wear out?

Friction also makes things wear out. There is always friction when the tires of an automobile roll along the road. If friction did not hold the tires to the road, the car would slip and slide on a dry road, as it does when it is raining. (We know it is the water between the tires and the ground which makes a car skid in rainy weather.)

The tires rub a little on the road, and as it does so, some of the molecules are pulled off from the whole tire so far that they do not jump back on again. The tire also wears out because in going over uneven and bumpy roads, little pieces of the tire are torn off.

Of course, they are so small that when a few of them jump off we cannot notice it. But after a long time, so many of them have jumped off that quite a bit of the tire has been worn away, and it cannot be used any more.

Our clothes wear out for the same reason. Stockings wear out at the knees usually, because every time we kneel down to play, there is a rubbing between that part of the stocking and the ground. Sleeves often wear out at the elbow, because every time we bend an arm, the cloth is rubbed against the hard, sharp surface of our elbow and this causes friction.

Why do we oil machinery?

There is always friction between any two parts of machinery that touch each other while the machinery is in motion. When we put oil between the parts, there is much less friction,

because each part touches the film of oil. Oil is smooth and so there is little friction when the parts of the machine touch oil instead of rubbing against each other. By making friction so much less, we can make machinery last a great deal longer.

Machinery will also run much more easily and quickly when it is oiled. The heat of friction makes the parts of machinery swell and forces them closer together than they are supposed to be. When this happens, it is harder for the machinery to work smoothly. By oiling the parts, we help to keep them from touching each other and so the whole machine will work more easily.

Chapter III

WHAT HEAT CAN DO

Why does water sometimes turn to ice?

WE KNOW that water becomes hard and turns into a solid called ice, when the temperature goes down to 32 degrees, but this happens so naturally and so conveniently for us, that usually we do not give any thought to it, or wonder why this happens. We also know that water turns to steam and disappears in the air when it is heated until it boils. There are reasons for both these changes in water.

Water is made up of molecules, as everything else is. But in water, the molecules do not stick so closely together as they do in solid materials, such as wood or steel or glass.

Heat has the power of dilating: that is, it pushes these molecules somewhat apart from each other in spite of their own power to stick together. When sufficient heat is applied to

water, it changes to steam. Scientists divide things into three groups called gases, liquids and solids; such as steam, water, and ice. Steam is a gas which contains the same molecules as water, but farther apart. In steam, they do not stay as close together as they do in water.

Adding heat to water changes it into steam. We are not surprised that an equally interesting change occurs when heat is taken away from water. As we know, liquid water turns into solid ice when enough heat is taken from it. If heat makes molecules expand or spread apart, cold forces them closer together. If we take a pan of water from a warm room and set it outside where it is very cold, the molecules in the water begin to move closer together. When the temperature goes down to the point we call freezing (32 degrees Fahrenheit), the molecules become so compact that the water forms a solid mass called ice.

Heat causes molecules to expand. Cold makes them contract. Usually contraction causes shrinkage, or makes a thing smaller.

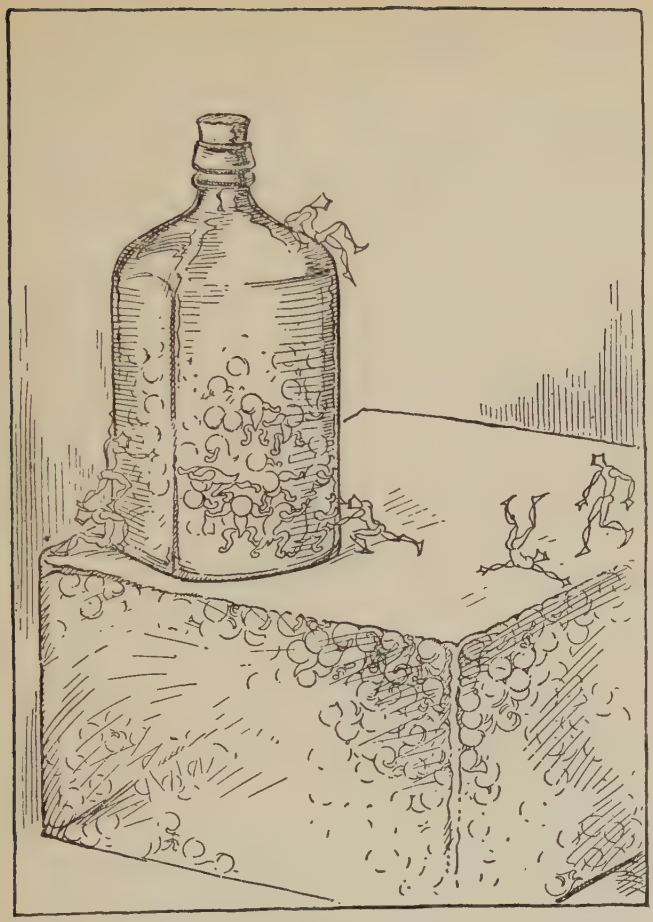
Most things take up less space when they are cold than when they are hot. But water is an exception to this rule. Just before water freezes into a solid mass, it expands somewhat or becomes a little larger.

If a pan is filled to the brim with water, when it freezes the ice will extend out above the top of the pan. A bottle filled with water and corked tightly will break if the water is frozen. The ice needs more room, and as there is none in the bottle, it will break the glass as it pushes out if it cannot force out the cork.

In the winter pipes in a building which carry water to the faucets will sometimes burst. If water is not being used frequently and stands still in the pipes, it may freeze in extremely cold weather. As ice it will need more room than the water did, and will break the pipes as it spreads out.

What makes water boil?

Water, like everything else, is made up of molecules. If we could find a microscope powerful enough to show the molecules in water or in anything else, we could see that they are



The ice needs more room as it freezes and it will break the bottle as it expands

always moving about. Heat makes these molecules dance around faster. The hotter they get, the faster and farther they jump around. When a kettle of water is set over a gas flame, the heat from the flame comes through the kettle and makes the water hot. As the water becomes hotter and hotter, the molecules in the water jump around faster and faster. Finally, they jump so far that the ones near the top of the water jump away from the rest right out into the air. When the water gets so hot that this happens, we say it is boiling.

When water boils, many of these molecules bounce out into the air. If we look carefully at a kettle of boiling water, we can notice that for a space of about an inch from the open end of the spout we see nothing. That is because steam is invisible. The molecules that jump out are so small we cannot see them. But by the time the steam gets about an inch away from the spout, the air, which is of much lower temperature, cools the steam and it condenses into tiny droplets of moisture in the air. This

Finally the molecules near the top jump away from the rest of the water right into the air

we call vapour, and it is this cloud of vapour which we see rising from the kettle when the water is boiling. If we turn the gas flame higher after the water has started to boil, we cannot make the water any hotter. Instead of getting hotter, more and more of the molecules will jump out into the air and form steam. If we wait long enough there will be no more water left in the kettle, because all of it has turned to steam in the air.

Why do tires sometimes blow out in the summertime?

When heat makes the molecules in a thing try to jump away, they spread out and make the thing a little bigger than it was before.

Sometimes when an automobile is left standing out in the street with the sun blazing down upon it for a long time in the summer, one of the tires will burst. That will happen because the extreme heat of the summer sun will cause the air to expand until it needs more room than there is inside the tire. The rubber of the tire may expand a little from the heat, but it will not expand as much or as quickly as the air

does. So the air will finally push on the tire until it bursts right through.

Why do floors sometimes make a crackling sound?

In winter we have steam heat in our rooms all day to keep them warm. This heat makes the wood in the floors swell a little. Then at night the heat dies down in the radiators, and we open a window to let in fresh air. This makes the room cold, and then the wood in the floor shrinks back to its right size. As it does this, we hear a cracking sound.

Why can cement roads not be made in one piece?

When we drive along a wide road of cement or concrete, we notice a strip several inches wide which runs along the middle. This strip is usually made of tar. And every little while we also see a short, twisting strip of tar in the road. The strip in the middle was put there when the road was made. The road is made in two parts with a little empty space in between. This is done so there will be room for the road to spread in the summer when it gets hot. After the road has settled, there is still a small crack left, and this is filled with tar. Sometimes, even after the road is made, it

shrinks or contracts in cold weather and leaves little wriggly cracks. These also have to be filled with tar to make the road smooth. If the cement were put down all in one piece, it would swell when the weather got hot, the road would be full of cracks and would wear out quickly.

Why do we open windows both at the top and bottom?

To get the best circulation of air in a room, we try to let fresh air in and force used air out at the same time. Air that we have been breathing becomes warmer than fresh air, because it comes from our bodies which are warm. The colder the air is, the heavier it is. Heavy air will sink down in the room and force the warmer air up, toward the top. So we open a window a little at the top to let out the used, warm air which it up high, and we open a window a little from the bottom to let in the fresh, cooler air.

Chapter IV

THINGS IN MOTION

A BALL made of rubber will bounce. A hollow ball made of celluloid bounces, and so will balls made of some other things, such as tennis balls. We know balls do not bounce just because they are round, for a ball made of string or of dirt or of clay will not bounce. Rubber balls bounce because they are elastic.

Why does a ball bounce?

We say things are elastic when they try to go back to their original shape after they have been forced to change it. When a rubber ball is thrown to the ground, the part that touches the earth is flattened out. Because the rubber is elastic, it tries to become round again. To do this, the ball will push itself away from the ground, and that will make it spring into the air. Many things are elastic, but some are

more elastic than others. Rubber has a great deal of elasticity and that is why the ball bounces so high. A baseball is made of twine and it does not have much elasticity. But it has a little bit, and if we bounce a baseball hard, it

The part that touches the ground flattens out and when it becomes round again it pushes itself away

will jump up a little from the ground. Glass is also somewhat elastic, as we can see when we make marbles bounce.

We use rubber bands to bind up packages because rubber is so elastic. We stretch the rubber band until it goes around the package. To do this, it is pulled out of its own shape, and so it tries to regain its own size. As it does this, it presses very hard on the package all around, and so holds it together.

If we try to make a top stand on its point, it falls over as soon as we take our hands away. That happens because there is more weight toward the upper part of the top, and it naturally falls in a position which brings the center of weight toward the ground. But when we spin a top, it stands on its point as long as it keeps spinning. When it begins to whirl more slowly, the top begins to wobble, and at last it falls because gravity pulls the heavier part down towards the earth.

How can a top stand on its point when it is spinning?

We wonder why gravity does not pull the heavier part down while the top is spinning, as well as when it is at rest. So we are ready to learn that there is another power which makes things move in a certain direction, besides gravity. *This force* which causes a thing to want to keep on going in the direction in which it starts to move is called *inertia.*

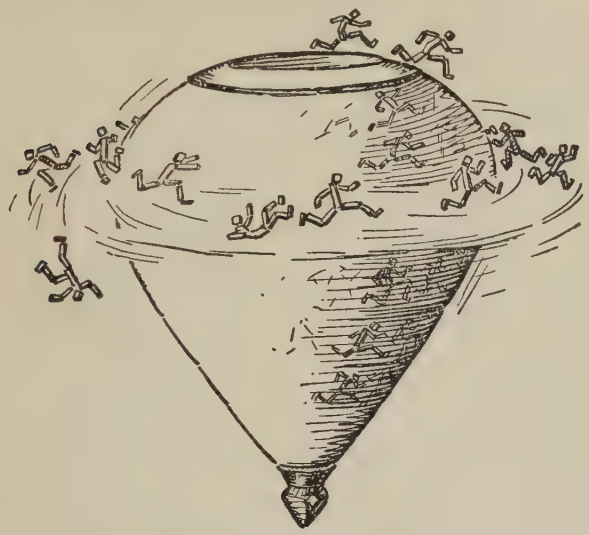
In whirling things, this force makes bodies tend to fly away from the center and is called *centrifugal force.* This is seen plainly when one stops to think what happens when a top

spins. When a top starts spinning, all the molecules in it are moving around and around in circles. As they do this, they tend to fly out, or away from the center of the top. The faster it spins, the harder the molecules try to fly out in the direction they first started to go. The force which makes them fly away from the center is stronger than gravity while the top is spinning. The molecules pull just as hard from all sides of the top, away from the middle, and so the top will balance on its point. But as it slows down, the force of gravity is stronger, and the top will fall over on its side.

What keeps the earth in its orbit?

The sun is so much bigger than the earth that its gravity could pull the earth toward it, just as the earth pulls on smaller things. But the earth is always flying around the sun very fast. This makes the whole body of the earth try to fly away from the center. The sun is the center of the orbit in which the earth travels. This force is exactly equal to gravity as long as the earth keeps whirling. That is why the gravity of the sun does not pull the earth toward

it. If the earth ever stops whirling around the sun, it will crash into that great burning ball and be burned up by its heat.



All the molecules are moving around in circles and try to fly out in the direction they started

Why does a bicycle keep moving after we stop pedaling it?

If we race a bicycle by pedaling quickly and steadily for a while, it continues to go for some time after we lift our feet from the pedals. Soon it slows down, however, and unless we begin to pedal again, it stops moving altogether.

It stops because gravity pulls down on the wheels, and thus increases friction which tends to keep the wheels from going around. But if friction tends to keep the wheels from moving, why does the bycicle move at all after we have stopped pedaling?

The wheels keep going forward because all things continue to move in the direction in which they have started. At least, they tend to keep moving until gravity or friction brings them to a stop. Once the wheels of a bicycle have started going forward, they keep going in that direction and in a straight line until they are stopped by an outside force. If there were no friction, the bicycle on level ground would continue to go until it ran into something, like a fence or a house or a tree.

It is true that everything tends to keep going, once it is started moving, until it is stopped by something else. It is also true that a thing which is not in motion, will never move unless it is started by an outside force. Leaves never rustle until the wind pushes them about. Water

in a pond does not move unless the wind ripples it. And once our bicycle has stopped, it will not go again until we give it power by working the pedals.

No object that is in motion will stop until an outside force makes it stop, and no object that is standing still will move until it is made to move by an outside force. *This is called inertia.*

Why is it hard to stop roller skates quickly?

If we are racing along on roller skates and wish to stop quickly, we have to take hold of something and hang on to it. Even when we grasp a post, we have to hang on tightly to keep from being pulled away from it, because our bodies keep on moving for a while. The skates and our bodies try to keep going in the way they have started. When we stop by holding on to something, the skates go on for a foot or two, with our feet on them, and we are likely to fall if we don't hold tight. If we are skating fast, and try to stop by taking someone's hand, we often find we cannot come to a halt, but instead of this pull the other person along with us. This happens because inertia

also makes our bodies try to keep moving the way they were going, even after we strive to stop them.

When we ride on trains, we move forward with the train and at the same speed as the train. If the train stops suddenly, we lurch forward. Inertia makes our bodies try to keep going forward just as they were moving before the train stopped.

If it were not for inertia, we could not throw things. As soon as we let them go, gravity would pull them down just as if we had dropped them. But when we want to throw a ball, we take the ball in one hand. Then we raise that arm, and also draw it back a way. As we bring it forward again, we start the ball moving in that direction. When we let the ball go, it keeps moving, because of inertia. But gravity pulls on it, and finally forces the ball to the ground. If gravity did not do this, the ball would keep moving in a straight line until it hit something strong enough to stop it.

Unless we keep swimming, when we are in

deep water, we find ourselves sinking. Our weight does not change because we swim or stop swimming, and the weight of the water remains the same. So we know that the motions we make when we swim keep us on the surface of the water, as well as make us go forward.

Why does swimming make us travel in water?

When we are taught to swim, we are warned to keep our fingers close together, and not let the water get through. In this way our hands become flat and solid like a paddle which exerts pressure against the water. Every time we bring one hand forward overhead, we push it backward through the water. As we do this we also push some of the water back. And as we push the water back, we force our body forward. This is called the law of action and reaction. We push the water in one direction: that is action. Our body moves in the opposite direction: that is reaction. While we are in motion we keep afloat.

Action and reaction are always opposite, and equal. Without this law, nothing in the world

would move. When we take a step forward, our foot is really pushing the earth back a little, and that makes our foot go forward in the opposite direction, with equal force. But the earth is so large that it doesn't move enough to be noticeable. The same thing happens when the wheel of an automobile moves around. It keeps pushing the earth back as it moves forward. This can be seen if the car is going along a pebbly road. We cannot see the earth move back, but we do see the pebbles fly back as the car moves forward.

Chapter V

WHY WE SEE

DARKNESS is absence of light. As soon as the sun begins to sink, the earth loses some of its light. The farther down the sun goes, the darker it becomes, and after the sun has set and the clouds in the west have no more brightness, it becomes so dark that we cannot see anything clearly. Therefore, it is easy to guess that the earth gets light from the sun.

Why is the night dark?

Light radiates from the sun in rays, just as heat does. One single ray of light cannot be seen by itself. But many rays together form a beam of light. We often see a beam of sunlight shining through a window, or a beam of moonlight shining down on us at night, reflected to us by the particles of dust in the air.

We see the sun because it is so hot that it shines with its own light. Things that shine by

their own light are said to be incandescent. We see the stars because most of them are burning and are incandescent. But people and trees and houses and rivers and almost all things that we see around us do not have any light of their own. We see them because they *diffuse* light.

When light rays travel down to us from the sun, they touch things they pass. When a light ray strikes a thing, it bounces back from that object to our eyes. And there is something in our eyes which receives the image that the ray of light carries to them. If it were not for these rays of light which carry the pictures of things to us, and if all things did not diffuse light, we would never see anything.

We do not see things as well at night when the sun is gone, because there is not enough light from the stars to bring us a good image. But sometimes when the moon is shining brightly we see almost as well as we do by day. The moon is never as bright as the sun, because it is not incandescent. The moon itself is not glowing; it merely reflects light from the sun,

and sends it down to us. But it absorbs some of the light rays because its surface is not smooth. We get more light from the moon at night than from the stars, because the moon is so much nearer to the earth. If we could get up to the moon, we would see the earth shining in the sky. It would be reflecting the light from the sun to the moon, just as the moon reflects the sun's light to us.

The sun is many million miles away from the earth, yet light travels so fast that we seem to see things without having to wait for the light to reach us.

Electric light is also incandescent, and it sends out rays of light, just as the sun does, so that with its aid we see at night as well as by day. If we walk into a room, the rays of light from the bulb travel out and when they touch us, they bounce back in all directions and will bring an image of us to the eyes of other people in the room. This happens so quickly that people see us as soon as we enter. The time it takes for light to travel that short distance is so brief that

it seems as if they saw us at once. The time is only the tiniest fraction of a second.

Why can we see through a window pane?

Rays of light travel through the air, because air is transparent. Things are transparent when they allow light rays to pass through, without breaking, or diffusing them. Glass is transparent, and that is why it is used for windows, so that we can get sunlight into a room. The light rays come in unbroken and we are able to see the things outside. But some windows are made of special glass which will let in the light, but through which we cannot see objects on the other side. This is usually glass that has been frosted. This makes the surface dull and not very smooth, so that the light comes through, but the rays are broken or diffused, and we do not get an image of things on the other side. Material which lets in light in this diffused way is called translucent. A white window shade is translucent. It will let in light, but we cannot see through it. But if we pull down a dark green or black shade, it will keep out the light. What really happens is that as the light strikes

the shade, instead of going right through, it is absorbed by the shade. Things through which light does not penetrate at all are called opaque.

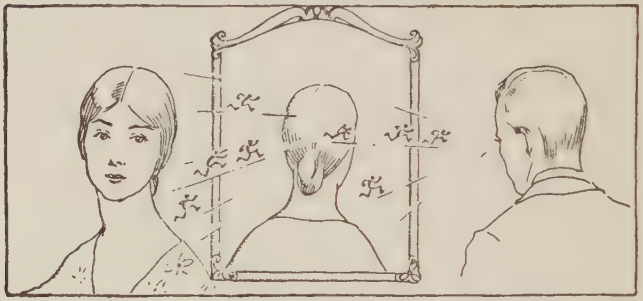
Frosted glass is used for electric light blubs because all the light comes through so that we can see clearly, but the rays are broken and do not shine directly into our eyes. This is restful and makes artificial lighting less of a strain on our eyes.

What is a mirror?

A mirror is usually made of glass. Anything that has a very smooth, shiny surface reflects light well, but if we use plain glass in a mirror, most of the light passes right through. Silver or mercury is usually put on the back of the glass. Silver and mercury are opaque. The light rays cannot penetrate them.

When light rays strike the mirror, they cannot get through. So they bounce back in the opposite direction, and in a straight line. If we stand directly in front of the mirror, light rays travel straight from us to the mirror. Striking the mirror, they bounce back again along the same line, and we see ourselves. But when

we stand at one side of the mirror, the light must travel in a diagonal line from us to the mirror. Then when it bounces back from the mirror, it will go again in a diagonal line, but in the



When we stand at one side of the mirror the light rays must travel in a diagonal line

opposite direction, like a ball bounced on a slant against a wall. That is why we cannot see ourselves when we stand at one side of a mirror. But if we stand at one side, and someone else stands at the other, we can see him and he can see us.

Anything that is smooth and glossy and opaque can be used as a mirror. A flat silver dish will reflect things as well as a mirror. If

the dish is not flat, the light rays will be bent so that we do not get an accurate picture. A pond or lake is smooth on the surface, and the water is shiny. That is why we see trees and clouds reflected in the water.

Why can we see ourselves in a window at night?

Glass window panes are smooth and shiny enough to act as mirrors. We find this to be true at night, when the room is brightly lighted and it is dark outside. Then we see ourselves in the window almost as well as we can in a real mirror. Everything in the room is reflected in the window panes. But in the daytime it is difficult to see reflections in a window unless the light is just right.

There is no difference in the glass at night. But we see these reflections then because there is more light inside than there is outside. The reflections are there in the daytime, but light coming through the window from the sun is so much stronger than the light in the room that it drowns out the reflections, just as a loud noise will drown out a softer noise. At night there is bright light inside the room, and none outside.

We see the reflections distinctly then because there is no more powerful light to hide them.

In the daytime, we see reflections in windows on the outside, for the same reason. If we walk along a street and look into a shop-window, we often see reflections of ourselves and other people walking by. We see them because the light outside the window is strong, and there is very little light inside to shine out and spoil the reflections which we see.

Why do the stars twinkle?

The stars we see in the sky at night are really great round balls like the earth and the moon and the sun. They send out light rays just as the sun does. But most of them are much farther away from the earth than the sun is. That is why they look so tiny to us. Some of them are burning and give off their own light. A few just reflect the light of the sun, as the moon does. But all of them are sending light rays which travel toward the eatrh. As these rays of light travel, they pass through uneven layers of air. This unevenness causes the rays of light to be bent in different directions as they

are traveling down toward the earth. It is really only the light rays moving back and forth that makes it seem as if the star itself were twinkling.

What is color?

We say that white things have no color. But white is not the absence of color. It is really all colors blended together. Sunlight is white light. A beam of light is white. Yet if we could see each ray of light in that beam separately, we would see that it had color.

There are six different colors in light. The longest rays are red. Rays that are a little shorter are orange in color. Yellow light rays are still shorter. Light rays that are a little shorter than the yellow are green in color. Blue light rays are shorter than green rays. The shortest light rays are violet.

The eye cannot detect the difference between pure orange and a proper mixture of red and yellow. A mixture of yellow and blue appears green to the eye, and violet may be imitated by a mixture of red and blue. Orange, green, and violet are sometimes called secondary colors,

because they may be imitated to the eye by mixing the socalled primary colors, red, yellow and blue.

These six colors are the only true colors, because they appear in the light rays. And all color that we ever see is reflected from light. The many different colors we use are made by mixing pigments which will combine two or more of these colors.

What are dyes?

When we have something dyed, we know it is dipped in boiling water in which some powder has been mixed. The powder has in it the color we want. At least we say the powder or dye is that color. But all color is really in rays of light. A certain dye looks red to us because that dye absorbs from the light every color but red. It reflects the red rays back at us so that when we look at the dye, it appears red. When we want to make a blue dye we use something that will absorb all the colors except the blue we wish.

Leaves are green because they absorb every color but green, and the green is reflected back.

A prism will bend a ray of sunlight into the colors which make up light

What makes a rainbow?

We never see a rainbow except after a shower when the sun comes out just as soon as it stops raining, or even before it has stopped raining. If we are in a place where we can see the whole arc of the rainbow across the sky very plainly, we can find most of the six colors, red, orange, yellow, green, blue and violet. These colors show in the sky because there are still rain drops in the air when the sun comes out. As the sunbeams travel from the sun to the earth, they pass through the drops of moisture hanging in the air high above the earth. When this happens the rays of light separate and we see each color by itself, as we do in a prism. A rainbow does not last long because the heat of the sun evaporates the moisture from the air. As soon as this is gone, the colors in the white light are no longer broken up.

When we blow soap bubbles, we see the same colors in the bubbles that we see on wet, oily asphalt. This happens because very thin films of water or oil can break light up into different colors.

The rainbow is sunlight divided into its colors by the water drops in the sky

What is iridescent glass?

Sometimes we get glasses to drink from which shows the same colors we see in the soap bubble. This colored glass is called iridescent. It has been specially made in such a way that light is broken up when passing through it. When light rays are split in this way, the different colors are reflected back to our eyes by this special glass.

What makes the sky blue?

When there are no clouds in the sky and the sun is shining brightly, the sky looks blue. Yet we know that the sky is nothing but air far above the earth. And air is a gas which is invisible and has no color. But as the rays of sunlight pass through the air, on the way to the earth, the molecules of gas which make up the air scatter all the colors which make up the sunlight. But the shortest colors are scattered most by the gas molecules. Violet and blue are the two shortest colors, and that is why the sky looks blue to us.

Is black a color?

Black is not a color; it is the absence of all light. And when there is no light, there can be no color, so black is the absence of color. Trees

and buildings look black at night. Almost everything looks black at night out-of-doors where there is no artificial light. There is scarcely any light from the sun at night, and when there is no moon, we do not get enough light from the stars to give things color. White houses will stand out more clearly at night than anything else. That is because white absorbs no color, so that even if there is little light, all of it is reflected back to us by the white building and it shows up better than the dark trees or a dark building.

When we look down into a very deep hole that is not very wide, it seems to be black, although the hole is really nothing but air. Light cannot penetrate to the bottom of the hole, and because there is no light down there, it looks black.

Why are we cooler in white clothes in summer time?

White cloth absorbs no color. It throws back to us all the light rays that strike it. When cloth absorbs light, instead of reflecting it back to us, it changes light into heat. A cloth that will absorb only one color and reflect the others, will

have only a little heat. The more colors it absorbs, the more heat the cloth will have. White cloth does not make any heat, because it takes in none of the colors. That is why clothes made of white material are the coolest to wear, and the most comfortable for hot weather.

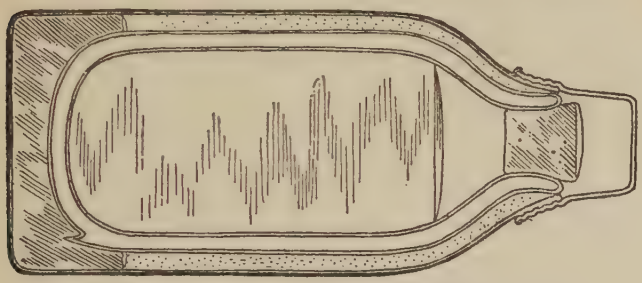
Black cloth is the warmest, because it absorbs all the colors and changes them into heat.

How does a thermos bottle work?

If we put hot coffee or soup or any hot liquid into a thermos bottle and cork it tightly, the liquid will remain hot for at least a day. But a hot liquid put into an ordinary bottle cools in a short time. If we take a thermos bottle apart, carefully, we can understand why it is able to keep things hot.

A thermos bottle is made of two layers of glass inside the metal covering that we see. A vacuum is made between these layers, by drawing out all air and sealing the two pieces of glass together at the top of the bottle. The hot liquid is poured into the bottle, and the heat cannot escape because there is no air to conduct the waves of heat.

But if the bottle were made with ordinary glass the liquid would soon cool anyway. The reason is that there is a kind of heat that *radiates*.



The thermos bottle has a double wall of silvered glass with a vacuum between

And radiating heat can pass through empty space on waves of *ether*. Scientists do not know just what ether is, but they use that name for matter which exists where there is nothing else. There is nothing, not even air, between the layers of glass. Yet the heat could get through. It cannot be conducted, because there is nothing to conduct it. So it is thought that there is some invisible matter that carries heat waves, and it is called ether.

The glass in the thermos bottle, however, has

silver on it. This makes it act like a mirror. When the radiant heat strikes the silvered glass, it is reflected back into the bottle, just as light rays would be. In this way it can not get past the glass, and the liquid inside is kept hot.

If we put something very cold in the bottle it will remain cold in the same way. The heat outside the bottle cannot get in because it is reflected back when it strikes the silvered glass.

How is the earth warmed?

The sun gives us heat as well as light. But the sun is about 93,000,000 miles away from the earth and there is no ordinary matter in this space to conduct heat to us from the sun. If heat could only reach us by being conducted through the air, it would have no way of getting from the sun to the layer of air around the earth.

So we see there must be some other way for heat to travel which will explain how it gets through all the empty space between the sun and earth. Scientists who have studied this problem have decided that there is a kind of heat which they call radiant heat.

In the space outside the blanket of air, there

is nothing; no molecules of any kind. Most scientists think this space is filled with an invisible substance not made of molecules and which they call ether. This ether is supposed to fill all empty space, even the tiny spaces between molecules.

The molecules of the sun are moving about very rapidly because the sun is so hot. This causes the ether up there to move about and make ripples. These ripples spread through space with great rapidity. They travel from sun to earth in about eight minutes. Heat radiates in this way through empty space. When it strikes anything, some of it is absorbed, and is changed into the usual kind of heat. When this radiant heat strikes the layer of air around the earth, some of it is absorbed by this air, and the rest of it travels through the air to the earth.

Radiant heat is very much like light. But heat that is radiating as ether waves cannot be seen. Light radiates through space as shorter ether waves, and these waves can be seen.

How does a fire warm us?

When we build a fire in the grate, it makes the whole room warm. It cannot be conducted to us through the air, because the air right around the flames which is warmed rises up through the chimney, and does not come out into the room. So it probably is radiated heat from the fire which warms the air all over the room. The heat travels from the fire on ether waves, because there is ether between the molecules in the air.

Why do some things feel warmer than others in the same room?

When a fire is burning in a room, the temperature is almost even in every part of the room, yet some things we touch seem much warmer than others. One thing is not really warmer than the other. What happens is that if we touch one thing it draws a lot of the heat out of our hand because it is a good conductor of heat, and that makes our hand feel cool when we touch that object. We then touch another object which is not a good conductor of heat. Most of the heat stays in our hand, and the object feels warm to our touch.

Iron is a good conductor of heat. If we leave

one end of a poker in the fire, the whole poker will soon get very hot, because the iron conducts the heat from the fire and travels from one end of the poker to the other. Silver is a good conductor of heat. A spoon left in a bowl of hot soup will quickly get hot all over. Rubber is not a conductor of heat, and a piece of rubber is put into a handle where it is joined to a pot. This keeps heat from traveling up through the handle, and we can hold it without burning our fingers. Asbestos does not conduct heat and does not burn. That is why theater curtains are made of asbestos, to prevent fire spreading from the stage to the auditorium. In that way, if a fire starts, one part of the theater is protected, and people can get out without being hurt.

Chapter VI

WHAT WE HEAR

What is sound?

WE HEAR with our ears, but sound is not *made* by our ears. We know this because if we hold our hands over our ears or stuff them with cotton, we do not hear very well. The sounds we hear are caused by something outside our ears; they may come from close by and be soft noises, or they may come from far away and be loud noises. How do all these different sounds get to our ears?

All sound is caused by motion. The motion sets up ripples in the air which spread out in ripples as water spreads when we drop a pebble in a pool. These air-ripples are called vibrations, and they keep traveling until they reach our ear-drums. When they strike these we hear the sound.

When someone speaks, he forces air through

his vocal cords. This makes the person's throat vibrate. These vibrations cause the air around his mouth to vibrate, and send out ripples. When these vibrations reach our ears, they cause our ear-drums to vibrate in the same way, and we hear the words the person spoke.

All sound is vibration. Every different movement causes a different vibration and that is why we hear so many different kinds of sound. If someone plays the piano, the hammers hit the strings in the piano. This causes the air around the strings to vibrate. These vibrations travel through the wood of the piano (because wood is a conductor of sound waves) and spread through the air until they reach our ears. Our ear-drums vibrate in the same way, and then we hear the melody that is being played on the piano.

When we play one note on the piano we do the same thing as when we play another. Yet the pitch, or tone of each note is different from the others. That is because the more slowly the body vibrates, the lower the tone of the sound

will be. The strings at one end of the piano are long and fairly heavy. As we go up the scale, each string is shorter and thinner than the one before it. The longer the string that is hit, the more slowly it vibrates. And the fewer vibrations per second, the lower the tone.

Can sound travel only through the air?

Air is not the only conductor of sound. There are things through which sound is carried more quickly than through air. Water carries sound. If we hold our heads under water, while we are swimming, we hear the people around us. And if we hold our hands above the water and clap two stones together, we hear the sound they make. But if we hit two stones together under the water, and keep our head in the water too, we hear the sound even more clearly, because sound travels better through water than it does through air.

Wood is a conductor of sound. If someone stands six feet away from us and takes a watch out of his pocket, we cannot hear it ticking because air will not carry that small sound far enough to reach our ears. But if a log six feet

long is lying near us, and we place a watch against one end, and bend down and hold our ear against the other end, we hear the watch tick quite distinctly.

What makes a room soundproof?

The harder a material is, the better it carries sound. Steel lets sound travel through it more quickly than through air. By listening to a steel rail we hear the sound of a train coming long before we see it or hear it through the air.

But some materials do not carry sound at all. If the walls of a room contain a substance which does not let sound waves through, the room is soundproof. Noise from inside the room cannot get past the walls to the outside, and noise outside the room cannot penetrate into it. Or if the walls were double, with a vacuum between the layers, there would be nothing which could conduct the sound through and the room would be soundproof.

What makes an echo?

We usually hear echoes more often in the country than in the city or inside of buildings. When in the country we sometimes notice that if we shout aloud, the sound of our voices comes

back to us the moment we cease shouting. We call this an echo, and what has happened is that the sound we make has bounced back to us. We may notice a mountain or a stone cliff nearby. But even if it is not in sight, there is always apt to be some sort of elevation not far off. And when we call out, the vibrations travel through the air until they strike this elevation. They cannot get through it, and instead of stopping there, the waves bounce back, just as a ball would. They travel back the way they came and finally hit our own ear-drums, and we hear the sound of our own voices. If the mountain is quite near, the echo will come quickly. It will take a longer time for us to hear the echo if the mountain is farther away.

Sometimes we hear an echo in a large theater or hall when there are only a few people in it. We would not hear this echo in the same theater or hall, if all the seats were filled. When the room is empty, sound waves travel out, and when they hit the walls they bounce back at our ears. But when the room is filled, the waves

strike the people and become smothered in folds of clothing.

Why do we see lightning before we hear thunder?

If we watch and listen to a thunder storm from the first stroke of lightning to the last clap of thunder, we notice an odd thing. At the beginning, lightning comes several seconds before the thunder. Sometimes a whole minute may pass between the two. Then, as the storm grows worse, the thunder follows the lightning with hardly a second between, although the lightning always comes first. Then, as the storm grows less furious, and seems to pass away from our part of the earth, again we hear the thunder long after the lightning has flashed. We know that the same thing causes both lightning and thunder, and that they happen in exactly the same place. A charge of electricity shooting from one cloud to another makes the flash in the sky we call lightning. This light sends rays down to us in waves. The vibration caused by this electric charge also sends waves to us which make the sound we call thunder. But waves of light travel very much faster than

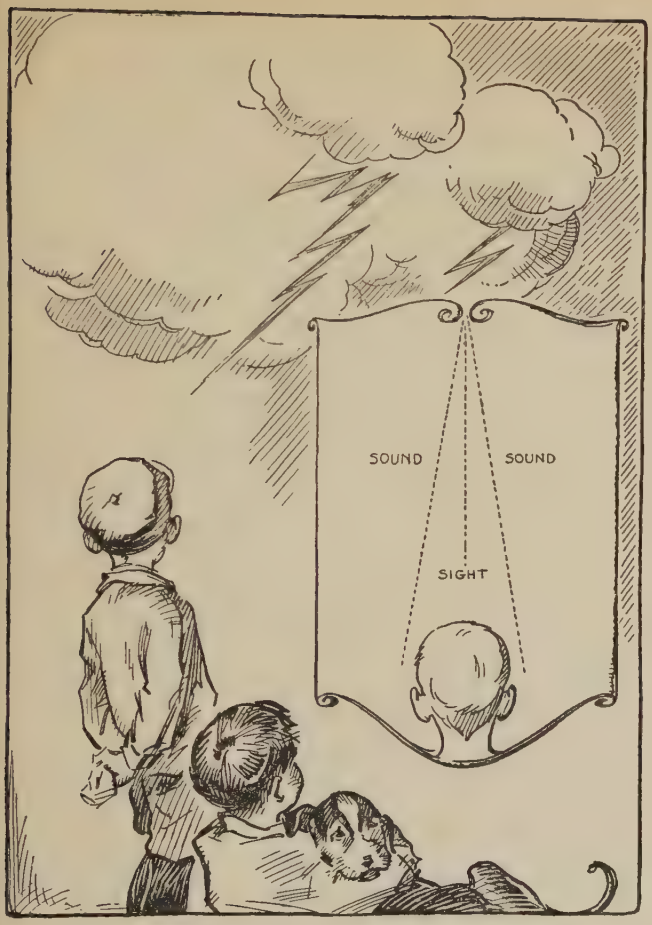
waves of sound. When the lightning comes from very far away, the light waves beat the sound waves in their race to the earth.

Why does an alarm-clock bell stop ringing when it is muffled?

Sometimes, when an alarm-clock rings in the morning, we are too sleepy to find the lever which stops the bell. So we put the clock under the blankets to muffle its noise. Putting something over the bell does not really stop the noise, but we no longer hear the bell's ringing; all we hear is a dull sound. This is because sound waves do not travel easily through the material of the blanket.

An alarm-clock rings because a knob inside it starts to hammer on the bell. This makes the bell vibrate. These vibrations travel through the air in waves which hit our ear-drums and we hear a ringing sound. When we cover the clock with a blanket, most of these waves can not travel to us and we do not hear the ringing. Some of the vibration does manage to send a few ripples through, and that is what makes the dull noise that we hear.

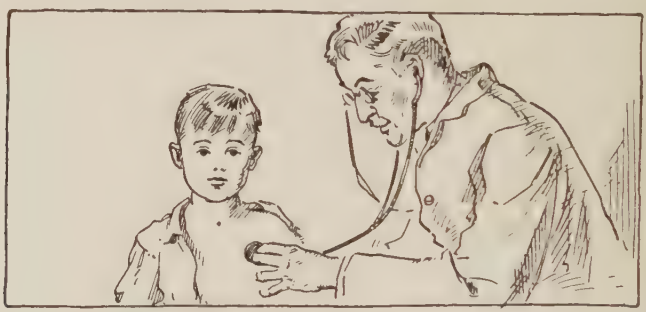
A stethoscope is the instrument a doctor uses



The light travels so much faster in the air than the sound that we see the lightning first

Why does a doctor use a stethoscope?

when he wants to listen to our heart-beats. It is made of rubber tubing, and looks somewhat like a wishbone, a very large wishbone. Two ends of it fit into the doctor's ears, and the other end is pressed against the patient's chest or back near his heart. A doctor can hear the heart beating if he puts his ear against the patient's



The air in the tubes of the stethoscope carries the sound to the doctor's ears

chest right under his heart. But he cannot hear clearly enough to be sure that our heart beats exactly as it should because the sound is not distinct. That is because the vibrations which our heart starts when it beats spread out in all directions. But when the doctor holds the

stethoscope tightly against the chest near the heart, the waves that ripple out from the vibration of the heart travel right through the stethoscope until they reach his ears. He will usually place the stethoscope against the skin, and not over our clothing. He does this because much of the vibration would be lost in our clothing just as it is in the blanket held over the alarm-clock.

What makes the music in a phonograph?

When we think how wonderful it is that we can hear any piece of music we want, simply by letting a needle travel round and round the grooves in a record, it seems like magic. But when we learn how these records are made we see that it is quite simple. When a record is made, a soft wax plate is used, instead of the hard rubber one we use to hear the music. This soft wax has no grooves in it. A soft needle is set at the outer edge of it the way we set the needle to hear a record. Suppose the record is being made by a man singing a song.

This singing causes the air around his mouth to vibrate in a certain way. Every sound makes

a different vibration. The air waves spread out into the horn and make the needle vibrate the same way. As the record moves round and round, the needle makes a wavy line in the soft wax which is just like the vibrations the man makes in the air when he sings. When he is finished, all those waves are marked on the record. From this master record, many other records are made, and all of them have the same wavy lines in their grooves. We buy one of these records. We put it on the phonograph, place the needle at the edge, and start the record moving around. The wavy lines in the grooves make the needle vibrate. This makes the air around it vibrate in the same way that it did when the man was singing. And so we hear the same sounds we should hear if the man were singing his song in the same room with us.

Chapter VII

ELECTRICITY

THE face of a compass is like the face of a clock, except that a compass is marked North, East, South and West instead of having numbers. The needle of the compass always points north. We may move the compass around so that the place which is marked North is really turned to the south or east or west, but the needle will remain the way it was, pointing toward the north pole of the earth.

Why does a compass point north?

The earth is like a huge magnet, with its north and south poles like the two ends of a magnet, which are also called poles. The compass needle is a magnet too. And *one* pole of a magnet, will always be drawn toward the *opposite* pole of another magnet. We might say that the point of the compass needle is its south pole. The south pole of the needle is

attracted to the north pole of the earth, and that is why the point of the compass needle is always turned toward the north.

When a compass is made, the needle is attached in its center to the center of the face of the compass. Thus it is free to swing about; and no matter how much we turn the whole compass around, this needle remains steady, so that its point faces north. The compass is of great value in keeping a ship to its proper course.

How is a compass needle magnetized?

A compass needle is made of steel. It is rubbed on a magnet, always in the same direction. It must be rubbed from one end to the other, always starting from the same end, and not going back and forth. Each separate molecule in the needle has poles which are called negative and positive poles, which are like the north and south poles of the earth. Before the needle is rubbed on the magnet, the molecules are lying every which way, facing in different directions. After the needle has been rubbed along the magnet, all molecules face the same

way, their negative poles facing one way, positive poles facing in the opposite direction. That is what is meant by magnetizing the needle. Once a piece of steel, or iron, has been magnetized it will remain in this condition even after it has been taken away from the magnet. That is why steel is used for compass needles. And no matter into how many pieces we break a bar of steel, after it is magnetized each piece is a magnet, with all its molecules facing in the same direction.

Why do we get a shock if we touch someone after walking on a carpet?

Electricity is made of tiny particles, which are the smallest things that man knows anything about. Nobody has ever been able to see such a particle, but men who make a study of electricity believe that every molecule contains particles of electricity, called electrons. And as everything is made up of molecules, that means that everything contains electrons.

When a thing contains an average number of electrons, nothing happens. It is only when things have too few electrons, or too many electrons that things begin to happen. When a

thing has too few electrons, we say it is positively charged with electricity. When a thing has too many, we say it is negatively charged with electricity. And things get charged with electricity, either positive or negative, by friction.

Ordinarily a person has just the usual amount of electrons in him. So has a piece of carpet. But as this person walks across the carpet, there is friction between his feet and the carpet. This makes some of the electrons in the carpet rub off and enter the person. Then he has more than the usual number of electrons and is negatively charged with electricity. Someone who has been standing still has less electricity in him than the person who has walked across the carpet. So that person is positively charged with electricity. When the one who is negatively charged touches the one who is positively charged, he will get a shock, because the extra amount of electricity in him jumps the short distance to the person who did not have so great an amount of electricity.

Any thing that is positively charged with

electricity will be attracted to another thing that is negatively charged with electricity. As we draw a comb through our hair, there is friction between hair and comb. This friction causes some of the electrons from the hair to rub off and jump to the comb. This extra electricity makes the comb negatively charged. And the hair is now positively charged. As we bring the comb near the hair, the hair reaches out and sticks to the comb for a second or two. We hear a crackling sound. That is the extra electricity jumping back from the comb to the hair. As soon as this happens, there is the same amount of electricity in hair and comb, and so the hair drops back on our head again.

Why does our hair sometimes jump out to meet the comb?

We notice this happening more in winter than in summer. In summer there is more moisture in the air. Moist objects are conductors of electricity; that is, the extra electricity in the comb goes into the damp air, and the comb does not have an extra charge of electricity with which to attract the hair. In winter the air is dry, and there is thus no place for the

electricity to go except from hair to comb and back again.

What is an electric current?

The kind of electricity got from rubbing things together and caused by friction is called static electricity. Static means standing still. When the electrons jump from the hair to the comb, they stay there. Then they jump back to the hair, but they do not keep moving after they return to the hair.

Electricity which flows along steadily is called an electric current. This is the kind of electricity we use to make things move, or to give us heat and light. Lamps, telephones, street cars, heaters, telegraph instruments, and many other things are all run by electric current.

What is a conductor of electricity?

Electricity flows through some things easily, other things will not let electricity flow through at all, while still others let only a small amount through. Water is a good conductor of electricity. It is dangerous to touch electric appliances when our feet are wet. If at such a time we touch a wire, the electricity goes through our body and gets from our feet to the floor by going

through the water. If our feet are dry, the current cannot jump from our feet to the floor because there is too great a space between them even though we do not notice it. And as long as the electricity cannot go into us at one point and out through another, we do not receive a shock.

Copper wire is a good conductor of electricity and is used for all electric wiring.

Materials through which electricity cannot flow are called non-conductors. Rubber is a non-conductor of electricity.

What is insulation?

Most electric current runs through copper wires laid under streets and brought into houses and other buildings in the cellar. These wires are double, one to carry the current into the house, the other to carry it back to the place where it is generated. These wires are covered, usually with rubber. This is done so that the electricity cannot escape anywhere and be wasted, or hurt anyone.

All wiring, inside of houses, which attaches lamps and other things to wall-outlets is bound

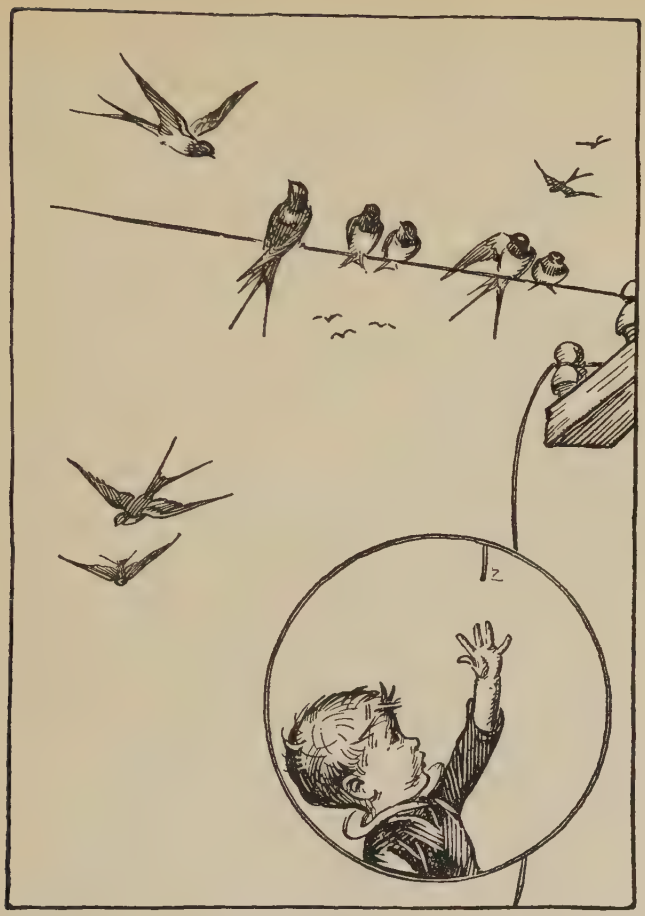
with rubber and silk, because they are non-conductors. When the electric current is covered so that it cannot escape, we say it is insulated. It must run through the copper wire because it cannot get outside the insulation.

Why can birds sit on telegraph wires without being hurt?

Wires which run from one pole to another along country roads are not insulated. The wire is not covered with anything and, if we were tall enough to reach up and touch the wire with one hand, we would be badly hurt by the electricity. Birds are conductors of electricity, just as human beings are. Yet they sit on these wires all day, and nothing happens to them.

The first thing to notice is that as the bird sits on the wire, no part of him touches anything else. If we could balance on a power line wire without touching the ground anywhere, we would not be hurt either. The electric current would run through the wire without going through us.

In order for electricity to run through us, it would have to be able to get back to the wire again. If we did not touch anything else, the



If we touch the wire when we are standing on anything, we get a severe shock

electricity couldn't get back to the wire after it went through us. But if we stand on the ground, electricity can go through us to the earth, and through the earth back to where the power line wire started. And as the current passes through us, the shock is very painful. Electricity always forms a circuit. It travels one way and comes back by another to the starting place. Sometimes instead of having a double wire, there is one wire which is grounded. That means it is connected with the earth somewhere, and so the earth can be used instead of a second wire. As the bird sits with both feet on the wire, the electricity does not flow through him because then it could not complete the circuit.

What happens when a fuse blows out?

Suddenly all the lights in one room, or in one part of a building, will go out at once. Someone says that a fuse has blown out. Usually that person goes to the cellar to fix something, and soon all the lights blaze forth again. In the cellar a box is placed quite near the spot where all the wires come into the building from outside. This box covers the electric wires. There

may be several different wires leading to different parts of the building. Each of these wires has its own fuse inside a box.

Where the fuse is put, the wire has been separated and is held together only by a fuse made of metal. The copper wire through which the electricity flows does not get hot. But if a great deal of extra electric current passes through it, it becomes hot, and if enough extra current passes through, it starts to burn. This starts a fire in the house.

The metal of which the fuse is made will get hot very easily. As soon as a little extra electricity passes through the fuse, the fuse metal becomes hot enough to melt. When the fuse melts, the two ends of the electric wire are separated. This stops the electric current, because it cannot jump from the end of one piece of wire to the end of the other. When the current stops, the lights go out.

An extra flow of electricity usually comes from a defect in the wire or in one of the electrical appliances, such as a lamp or toaster

or curling iron, etc. Defective wiring means that the electric current can flow through more easily than it usually does. Only a certain amount of electricity flows through the copper wire when it is in proper condition, because the wire is always resisting electricity. Sometimes there is a defect in the insulation and the electricity flows through too quickly because there is no resistance. We call this a short circuit, because it is easy for the electricity to get from one wire to another to complete its circuit. This makes the wires very hot and causes fire.

Fuses are cheap, and when they blow out it is easy to put in a new one. If we did not have fuses, the damage caused by short circuits would be serious.

What causes the light in an incandescent lamp?

If we look at the wire that connects a lamp with its outlet in the wall, we see it is a double wire covered with silk. Electricity flows into the lamp through one wire, and out again through the other. But as it flows into the lamp, it must go through something else before it flows out again. In an electric light bulb

there are fine wires that look like thread. These are made of a metal called tungsten. Electricity flows through these wires, which are called filaments, before it flows back through the second wire. And as the electric current passes through these filaments, it makes them glow.

We get this light because the filaments have great resistance to electricity. Resistance to electricity is something like friction, and friction causes heat. The filaments are made of metal that has this great resistance to electricity, and they are made more resisting because they are so thin that there is not room for much electricity to get through at a time. The filaments resist electricity so hard that there is a great deal of work done, which makes the metal white-hot. Metal will become white-hot when it is heated intensely. And white heat gives off light. If you can look at an electric light bulb, you see the tiny wires are bright and seem to be burning. That is what gives us the light. After much use, the filaments wear out because of the heat that slowly evaporates them.

In a lamp, the tiny filaments become white-hot and give us plenty of light. An electric heater may be connected to the same wall plug and give us heat instead of light. It will give off a little light, like a red glow, but not enough to see by.

How do we get heat by electricity?

There are wire coils in a heater, but they are bigger and thicker than the filaments in the light bulb. In these larger wires resistance to the electric current is not so great. There is not so much resistance, and so the wires do not get as hot in the heater as do the filaments in the bulb. The wires become red-hot, which is a degree of heat not as great as white heat. When wires get red-hot, they give off a great deal of heat, and not much light. The round metal part of the heater is used to reflect these waves of heat into the room.

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